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memorandum
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Accelerator Physics and Engineering Group

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SUBJECT: SNS CCDTL/CCL BEAM LOSS EXTRAPOLATIONS

In an attempt to estimate the beam losses for the high-energy sections of the SNS linac we have completed a series of simulations and used the results to extrapolate to various linac beam-pipe/bore radii. The results of these extrapolations are presented in this memorandum. As with all extrapolations, the results are dependent on the functional form assumed for the fitted function. This generally leads to large uncertainties in the extrapolated values, but sometimes some physical insight can be gained from the exercise. The main purpose of this memorandum is to document the results.

End-to-end simulations were first done using random alignment and operational errors. These simulations were used to determine the specific set of errors resulting in the largest emittance growth and maximum extent of the beam for the 10 cases that were run. Simulations were then repeated using this specific set of errors with reduced apertures in the 1.75 cm and 2.0 cm sections of the linac. For each simulation run, the aperture was reduced in this section of the linac and the corresponding fractional loss was tabulated. Table 1 shows the simulation results for simulations using 10,000 macroparticles and 1,000,000 macroparticles. Due to the long computation times required to run simulations using 1,000,000 macroparticles, the range of linac apertures was limited compared to the the 10,000 macroparticle case. This of course led to a reduced range of values to fit and reduced the number of degrees-of-freedom and therefore, the order of fit that could be achieved for this set of data. The fraction of beam lost in this section of the linac is shown as a function of beam-pipe radius in the table.

The data were fitted assuming that the tails of the real-space distributions fall off exponentially. Two figures have been included that show the fitted functions for the two simulation cases, their fit coefficients, and a plot of each fitted function with the plotted data. Table 2 shows the extrapolated fractional beam losses as a function beam-pipe radius. Also included in the table are the estimated losses in nA/m averaged over the entire section of the linac. This section of the linac was assumed to be 359.28 m long (Segment 129-345) for the calculations. As can be seen, there is a rather large spread in the results between the two extrapolations, for a different total number of macroparticles used, for beam-pipe radii of 1.5 cm and 2.0 cm.

Table 1 – Simulation results of fractional losses in the high-energy sections of the SNS linac using reduced beam-pipe radii to obtain data points for extrapolation fits.

Beam-pipe Radius	10K Simulation, Fractional Loss	1000K Simulation, Fractional Loss
0.40 cm	0.7348	-
0.50 cm	0.3881	-
0.60 cm	0.1230	-
0.70 cm	0.0330	-
0.80 cm	0.0118	0.00866
0.85 cm	-	0.00471
0.90 cm	0.0040	0.00252
0.95 cm	-	0.00131
1.00 cm	-	0.000673
1.10 cm	0.00048	0.000191
1.15 cm	0.000121	-

Table 2 – SNS linac extrapolated losses using the exponential fits to the simulation data.

Beam-pipe Radius	10K Simulation, Extrapolated Fractional Loss	1000K Simulation, Extrapolated Fractional Loss
1.2 cm	1.42×10^{-5}	5.48×10^{-5}
1.3 cm	3.62×10^{-9}	1.71×10^{-5}
1.5 cm	1.02×10^{-30}	2.39×10^{-6}
1.2 cm	0	7.77×10^{-7}
R=1.5 cm	1.59×10^{-25} nA/m	0.373 nA/m
R=2.0 cm	0 nA/m	0.121 nA/m

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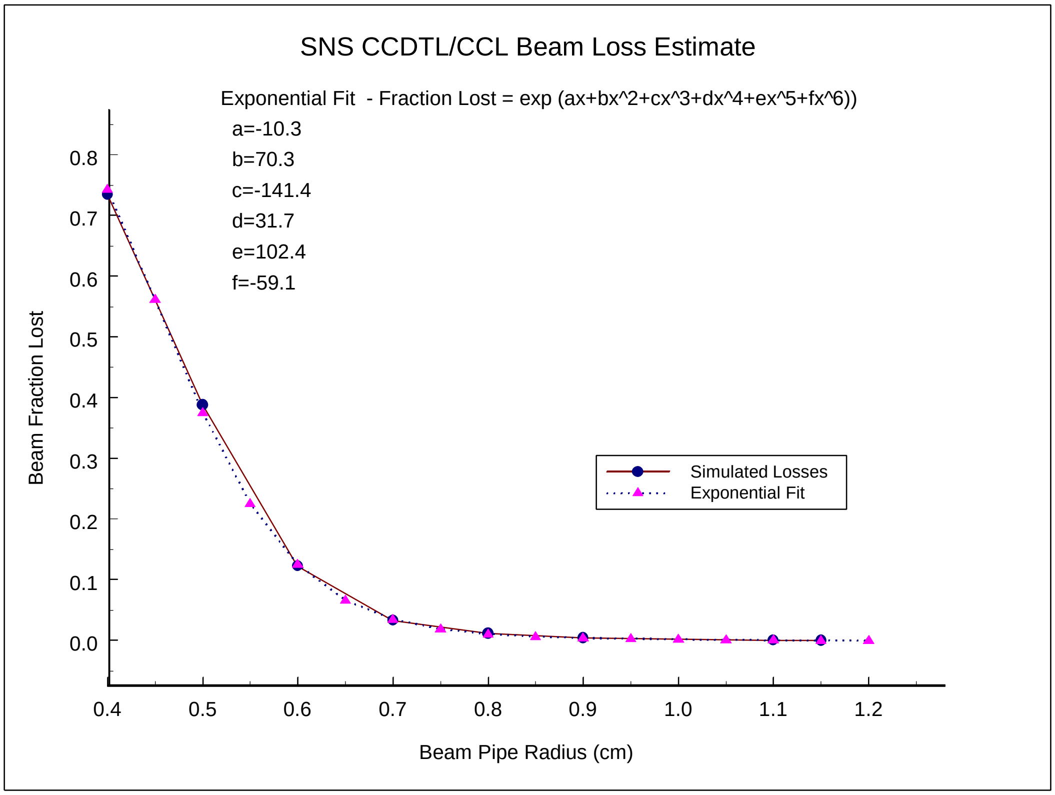
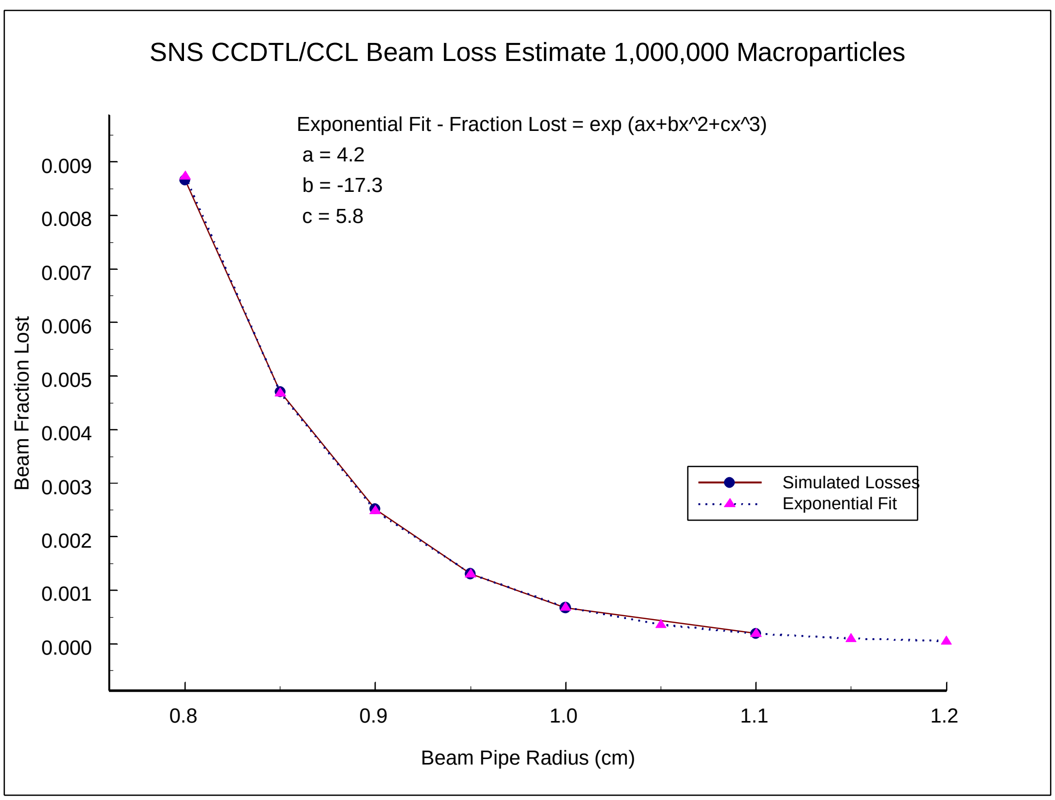

SNS CCDTL/CCL Beam Loss Estimate
Exponential Fit - Fraction Lost = exp (ax+bx^2+cx^3+dx^4+ex^5+fx^6))
a=-10.3
b=70.3
c=-141.4
d=31.7
e=102.4
f=-59.1
Beam Fraction Lost
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Beam Pipe Radius (cm)
Simulated Losses
Exponential Fit


SNS CCDTL/CCL Beam Loss Estimate 1,000,000 Macroparticles
Exponential Fit - Fraction Lost = exp (ax+bx^2+cx^3)
a = 4.2
b = -17.3
c = 5.8
Beam Fraction Lost
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0.8
0.9
1.0
1.1
1.2
Beam Pipe Radius (cm)
Simulated Losses
Exponential Fit